MUSEUM OF PRACTICAL GEOLOGY.

Government School of Mines and of Science applied to the Arts.

ON THE

VALUE OF AN EXTENDED KNOWLEDGE OF MINERALOGY

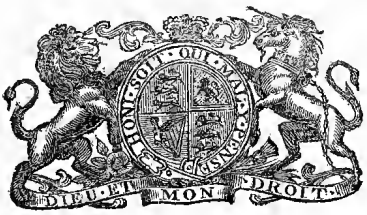
AND THE

PROCESSES OF MINING.

(BEING THE INTRODUCTORY LECTURE TO THE COURSE OF MINERALOGY AND MINING.)

BY

WARINGTON W. SMYTH, M.A. CAMBRIDGE, F.G.S., &c.,
INSPECTOR OF MINES TO THE DUCHY OF CORNWALL.



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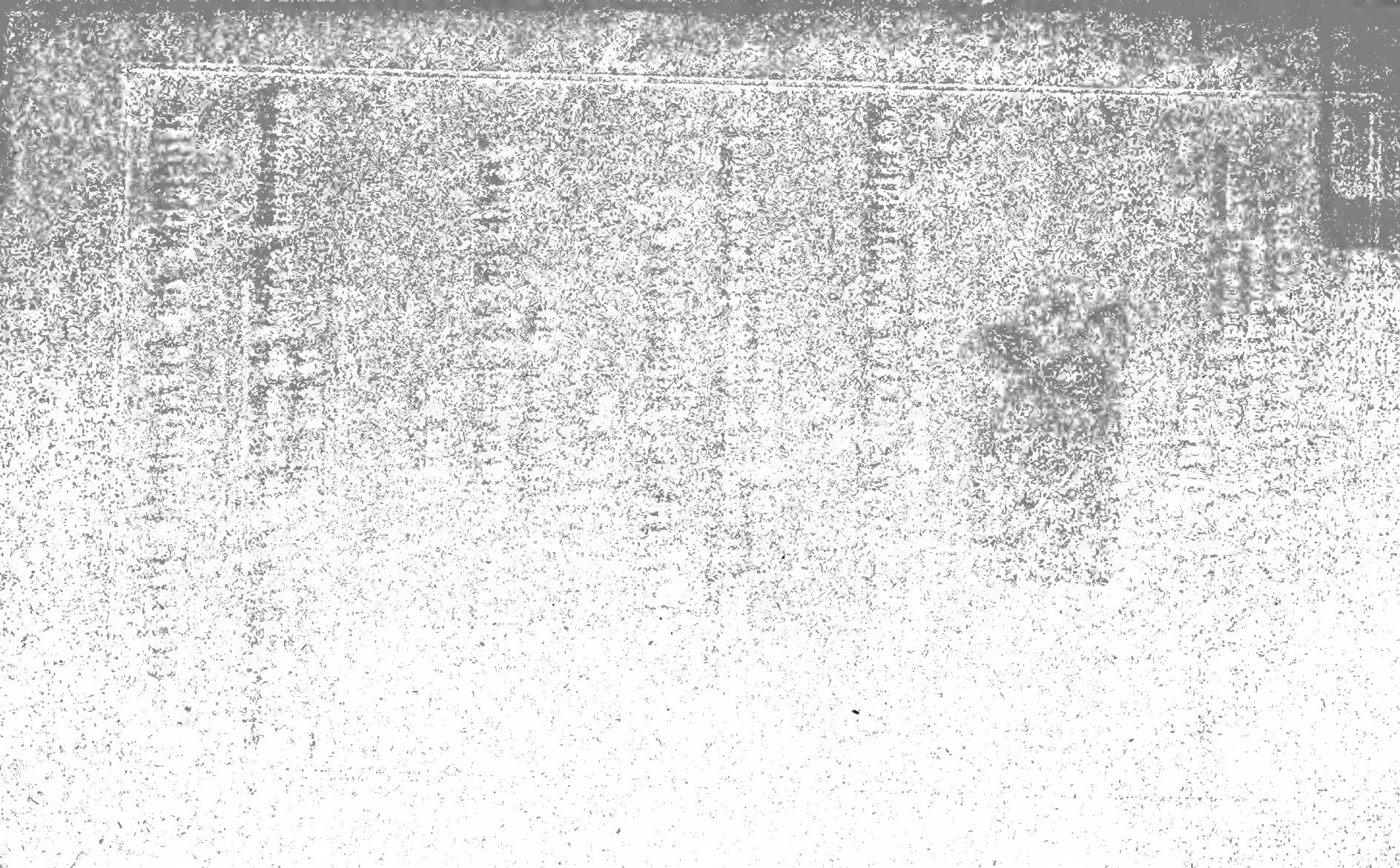

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Πολλαὶ τέχναι ἐν ἀνθρώποις εἰσὶν ἐκ τῶν ἐμπειριῶν ἐμπείρως εὑρημέναι· ἐμπειρία μὲν γὰρ ποιεῖ τὸν αἰῶνα ἡμῶν πορεύεσθαι κατὰ τέχνην, ἀπειρία δὲ κατὰ τύχην.—*Plat. Gorg.* (*Polus.*)

There are many arts among mankind which have been invented by the experienced, through the means of experience: for whilst experience causes our age to advance by the principles of art, a want of it leaves us dependent on chance.

Having been honoured with the charge of opening in this Institution a course of instruction on Mineralogy and on Mining, I deem it desirable in the outset to define the limits of these distinct although kindred subjects, and to point out the directions in which they dovetail into the other branches of applied science as treated by my colleagues. The technical character of the education to be imparted here will be the beacon which I shall endeavour to keep in view, that I may avoid being drifted by the current of thought too far into the wide expanse of general considerations, where in connexion with those studies so much that is beautiful and useful in ordinary life has already been acquired, and so much still remains to be discovered; but where in the meanwhile we might wander wide of the desired path. This discourse will therefore deal almost entirely with matters of practical application; and a number of examples which have been brought under my own observation during a few years past will be adduced in support of the proposition—that *an extended knowledge of mineralogy and the processes of mining are essential to those interested or engaged in mines.*

In the commencement of an inquiry into the infinite variety of objects surrounding us in the natural world, presented, it would appear, for the purpose of inducing the most attractive and holy exercise of our observing and reasoning powers, it is obvious that three principal assemblages are to be discrimi-

nated. These divisions are the animal and vegetable kingdoms, characterized by organic structure, and the wondrous phenomena of life; and the inorganic or mineral kingdom, comprising that far greater proportion of the materials of the planet in which no traces of organic structure are observable. This last assemblage of objects has been generally understood to form the province of mineralogy, which thus in its most extended sense would include all the aëriform and gaseous bodies occurring in nature, and could hardly venture to exclude the multifarious substances produced under similar chemical laws by the agency of man.

But since, amid the daily increasing accumulation of new and unexpected combinations, the domain of the inorganic kingdom appears unlimited, and many of its phenomena must be investigated by special departments of science, it becomes necessary to draw a boundary line around that portion of it which is to be embraced in modern mineralogy; and where we can find no logical distinction between the actual products of similar bodies and similar laws, as seen in nature or in art, we must, for the sake of convenience and utility, rest our criterion of separation upon the different conditions of their origin.

Under this point of view mineralogy has for its object the consideration of the natural inorganic materials of our globe, fluid and solid; the physical phenomena which they present, their chemical constitution, their modes of occurrence, the methods by which they are distinguishable from each other, their classification, and the uses to which they may be made subservient.

Now it is evident that as the characters of minerals are dependent partly on their form, partly on their chemical and partly on their physical properties, mineralogy must be based upon geometry, chemistry, and natural philosophy; and the history of the science affords the best proof that no branch of knowledge can rise towards perfection till the conterminous sciences have, after due cultivation, been brought forward to aid in its development. The student should therefore previously acquire a certain acquaintance with these auxiliaries; and it is for this reason that the lectures on chemistry and physics have

been so arranged as to precede the more compound subjects on which we are now about to commence.

It may at first sight appear trivial and unnecessary to insist on the definition and objects of mineralogy; but, in addition to the importance of a clear understanding of the purport of any branch of education, there are in the present case special reasons for adopting such a course. This science has in Britain, for many years past, been cultivated by so small a number of investigators, that by the public at large it has been almost lost sight of, and is not unfrequently confounded with chemistry, geology, or metallurgy. Nay, there are not wanting among scientific men those who assert, that as a mere department of chemistry it can hold no independent place, nor offer a foundation for a special course of study. The above definition, however, may aid in fixing its true position, and will show, that whilst we contend with such opinions on the one hand, we would oppose on the other the vain struggles of those who have endeavoured to disconnect the science from that chemical aid which has so much advanced its progress and heightened its interest.

The prime and grand interest attached to our studies of the products of the earth is to be found in the fact that the mineral properties of different lands, in conjunction with their geographical features, have determined the distribution, the physical and social character, and the well-being of the various races of man. Whether we examine the vestiges left by the peoples of gray antiquity, or study the modifications produced in branches of the same race located in regions of different aspect, or inquire into the origin of the chief seats of modern civilization, we shall be assured that most of these phenomena are dependent immediately, or through the medium of vegetation, on mineral produce, and the particular conditions under which it can be made available to human convenience.

In the remains of ancient Egypt we learn how a stupendous architecture arose by the aid of the soft yet massive sandstones piled by nature on the banks of the Nile, and how monolith statues and obelisks were suggested by the presence of a syenite capable of taking a high polish, and admitting of the sharpest intaglio tooling. In Attica the marble of Pentelicus and the

silver of Laurion combined to develope that high state of art which, exemplified in the Parthenon and the sculptures of Phidias, has never since been equalled; whilst the abrupt limestone ravines of Lycia and Arabia Petræa gave rise to a description of architecture peculiar to itself.

As examples of the second point, call to mind the different occupation and character of the dwellers in the Spanish peninsula,—the active mining and mercantile population of Gallicia, Asturia, and the Basques on one hand, the indolent Castilian and Portuguese on the other.* Or compare the torpid millions of the Slavic race in the plains of Russia with their industrious relatives and co-religionists in Servia and Bulgaria.†

Lastly, in furtherance of the third inquiry, we need only to examine the beautiful population map of the British Islands by Petermann, which shows at a glance that besides the conditions requisite for the purposes of shipping, it is coal and iron and lead and copper that mainly influence the increase of our towns. Nor can we omit to refer to the amazing process by which the discovery of gold is at this day pouring a new tide of population over parts of Siberia, to Western America, and to the Antipodes.‡

Such general views are, however, somewhat foreign to my purpose; for the main question which lies before me is the importance of mineralogical knowledge to those engaged in technical avocations. Enormous as is the interest at stake in connexion with this science, it is obvious that a more or less profound acquaintance with its facts must be productive of considerable differences in the progressive development of the national wealth. It is surely patent to all that the miner ought to be thoroughly acquainted with the nature of those substances

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* Le Play, Ann. des Mines, 1834.

† C. Weerth, "Die Entwickelung der Menschenracen durch Einwirkungen von aussen." Lemgo, 1842.

‡ Virlet, "Coup d'œil statistique sur la Metallurgie dans ses Rapports avec l'Industrie, la Civilisation, et la Richesse des Peuples." 1837. Ami Boué, "Der ganze Zweck und der hohe Nutzen der Geologie." Wien, 1851.

which it is his daily task to seek in the recesses of the earth, as well as with those which exert a favourable or a pernicious influence either on the abundance or quality of the objects of his search. No less should he be prepared to recognise those which, although unusual in the spot where he has commenced his career, may be thrown in his way either in another part of the same vein, or in neighbouring veins of the same district, or even in other lands, to which, by the varying demands for mining skill, he may so probably at some time be transplanted.

Supposing even that our miner had perfected himself in a science requiring far more close application to books and in-door study; supposing that he were an expert chemist, I venture to assert, that although in many cases highly serviceable to him, this rare acquisition would not make amends for an ignorance of mineralogy. Were he, each time that he required to know the nature of a substance, obliged to enter upon its chemical analysis, his days and years would be passed in endless labours often repeated and sometimes fruitless. If we concede that after twice or thrice analysing the same ore, for example, he were to recognise it the fourth time by some less laborious test, we allow, in other words, that he has acquired a mineralogical knowledge of that single substance: and thus we arrive at the conclusion, that the methods of mineralogy are those which a man must employ, if, in relation to the natural inorganic bodies, he desire to reap the advantages offered him by previous investigations.

There exists, it is true, in practice a source of difficulty which has probably gone far to prevent the spread of our science. Whilst many of the more abundant and valuable productions of the mineral kingdom are met with in such a state of impurity from mechanical aggregation and admixtures, that the particular minerals of which they are composed are not separable by physical means, others occur only in an amorphous or irregularly shaped condition. Now scientific mineralogy bases its descriptions on the most perfect individuals, or crystals, of each species, bodies which are comparatively rare; and treats with but little respect those which are never crystallised, and of which the distinguishing characters are less definite. It stands to reason that in an Institution of a practical tendency the strictness of

such rules must be relaxed, and that greater weight must be attached to those substances, chemically impure though they may be, which are abundantly yielded by our mines and quarries, and yet scarcely constitute true mineralogical species.

We shall thus, for example, study the characters of the pure carbonate of iron in the crystals occasionally lining the cavities of our lodes, in the masses which exert so powerful an influence on the industry of Nassau and the Austrian Alps, and again in those indefinite mixtures which as nodules and continuous beds have, from their geological position and abundance, contributed in a high degree to raise Great Britain to her present pinnacle of manufacturing power.

But the cause of such a preference in mineralogical works is at once evident, on comparison of the objects described with those of the other classificatory sciences.

In the animal and vegetable kingdoms the naturalist traces, in successive groups of animals and plants, a descending scale of lower and lower organization, till at last, in the most rudimentary forms of life, individuality is lost in an assemblage; yet down to this point each species presents none but forms complete in themselves, and almost unvarying. In the mineral kingdom, on the other hand, we are obliged to seek out for description the most perfect specimen, because it is not a succession of species, but the same species which offers a never-ending diversity of aspect. The mineral species may indeed occur in every state of development, from the symmetrical crystal, composed of definite constituents, passing through every grade of incompleteness of form or admixture with foreign substances, till we reach the lowest step of the scale, where the individual is so merged in the mass that form is destroyed, and the other characteristics are no longer discernible to the sense. How striking is the parallel in human societies, where the development of mind and resources unmistakeably accompanies such arrangements as lead to the self-reliance and importance of the individual, whilst as surely the crippled freedom of action caused by merging individuality in the crowd is attended by deterioration and destruction of all healthful prominences of character!

But besides the miner, there are hundreds and thousands

amongst us whose pursuits, bearing on the practical purposes of life, render a knowledge of mineralogy an element of success. The geologist, the engineer, and the architect must have recourse to mineralogy to gain acquaintance with many of the materials which they employ; nor, even if they possessed unlimited time and means for the acquisition of chemical analyses, could they afford to overlook the physical properties which are often chiefly instrumental in fitting those substances to their several applications. The agriculturist, if he wish to modify and improve the condition of his soils, must become familiar with the appearance and qualities of the marls, limestone, gypsum, phosphorite, and other minerals, which are now beginning to exert a remarkable influence on his art. The antiquary, without a knowledge of the stones from which the ancient inhabitants of the earth sculptured their idols, reared their temples, or fashioned their rude implements, and of the ores from which they produced their metals and alloys, can draw no sound conclusions as to the comparative civilisation of distant epochs, nor guard himself from the blunders consequent on faulty observation or crude description. Who, again, that is not insensible to the varied beauties of the brilliant gem, would hesitate to prefer to determine its nature by the methods of mineralogy instead of entrusting it to the chemist, who, with ruthless hand and devouring acids, must destroy its substance ere he can pronounce upon its character?

Other and numerous mineral productions there are for a decision on whose value we are dependent on the aid of analysis. Among the irregularly mingled bodies to which I have before alluded are many which, like the iron ores lately discovered in the oolitic formation, can only be determined as to their importance by accurate assay. Few among the crowds who at the late Industrial Exhibition swept by the series of iron ores brought together from all parts of Britain by Mr. Blackwell, could have prophesied that the collection of half a dozen of those sombre stones would give rise within a few months to an active industry, which bids fair to develope a new phase in the gigantic phenomenon of the British iron trade. An example, this, of the mutual dependence and assistance of three sister sciences, where geological reasoning had to point out the tract in which

a given formation was to be found, mineralogical observation to discover the actual deposit, and chemical analysis to determine the value of the ore.

The mining districts of Great Britain are so utterly destitute of the means of mineralogical education, whether in schools or suitable collections, that it need be no source of wonder to find the most intelligent miner acquainted only with some two or three of the substances, which in the routine of his employment have been brought prominently before him, and often neglecting others from ignorance of their nature, or dangerously confounding things which are totally distinct from each other. It is matter of history that the copper ores of Cornwall were recognised as useful only at a comparatively late date, the miners having concentrated all their attention upon the tin with which that county was so plentifully supplied. More wonderful does it appear, that even at the commencement of the last century, when the yellow ore or pyrites had been long appreciated, the far more valuable redruthite, or sulphide of copper, was thrown as worthless rubbish over the cliffs of St. Just into the Atlantic; and Pryce informs us, that "many thousand pounds worth of the rich black ore, or oxide of copper, was washed into the rivers and discharged into the North Sea from the old Pool mine."*

These might be considered as the errors of a past age, but we may recollect that they occurred at a time when the value of the same substances was understood in other countries; and by mere accidental rencontres similar cases are still not unfrequently brought to our notice.

During a visit, three or four years since, to a mine which was supported chiefly by raising blende, the sulphide of zinc, my attention was attracted by a lump of white mineral lying on the window-sill of the office, a single glance at which was sufficient for recognition; and I put to the agent a few questions regarding its nature and occurrence. He replied that it was nothing but "spar", and that in working a particular part of the lode they had met with many tons of it, which, however, had been all, except this accidentally preserved specimen, irretrievably mixed with the rubbish heaps. The surprise of my informant

* Pryce, Mineralogia Cornubiensis, 1778.

was not small, when he learned that the so-called "spar", confounded by him with quartz, was calamine, an ore containing in its pure state above 60 per cent. of oxide of zinc. Not to leave the same metal and its ores, which put on a great variety of characters, I have known zinc blende taken for lead ore, and honoured with the erection of a smelting furnace, when, to the chagrin of the manager, the volatile metal flew away up the chimney, leaving only disappointment and loss behind. Again, from a faint resemblance which some of the varieties bear to certain iron ores, a resemblance which would at once disappear before accurate observation, a considerable quantity was bought, not long since, by one of the greatest iron-masters in this country. It was carried to the furnaces, duly mingled with fuel and flux, and after a strenuous effort had been made to get it to yield iron, it all, as the proprietor naïvely remarked, "went off in smoke."

Blunders of this kind are more excusable when made in regard to some of the minerals of comparatively rare occurrence. An active agent of my acquaintance, a man of high character, was requested by a couple of his friends, who gave themselves credit for uncommon sagacity, to join them in forming a company to work a deposit of an unusual ore which they had lately found. Already they had referred it, for corroboration of their opinion, to a person at Birmingham styling himself a mineral chemist, whose report set forth that the specimen shown him was, as the others had suspected, an ore of molybdenum, and that it was worth 8*l.* per ton. This was sufficient to induce the agent to join the discoverers in a journey to the place in question, and at the head of a remote valley, embosomed among the rugged hills of Cambria, he was gratified with the view of such a mass of the same substance that it was evident that thousands of tons might be quarried at a mere nominal price. Specimens were broken, the party returned to consider the preliminaries of their adventure, and it was agreed that the mineral corresponded pretty nearly with the description of sulphuret of molybdenum in some book, which was at hand. Still, the more cautious manager feared that the prospect was too bright to be real, and without consulting the others, expended a fee in sending for a good analysis to a scientific chemist in London. The result was, that the substance in question proved to be a shining, black,

slate-clay, not applicable to any use, except perhaps to make bricks.

Within a gunshot of the place where the above-mentioned agent related this anecdote, the appearance of some rather ferruginous slate rock attracted the attention of a party of credulous speculators, who believing they had discovered a rich iron ore, actually built a blast furnace, erected the necessary machinery, and continued for some time to carry out their vain attempt, deluded by the fraudulent practices of the workmen. As might, however, have been predicted, the undertaking soon ended in abandonment and ruin.

In other mining districts I have known persons, who although possessed of great general intelligence, have collected blue stones (generally ores of copper) for cobalt, ignorant of the fact that none of the natural combinations of this valuable metal possess a blue colour.

The sulphate of baryta has for a few years past borne a certain value for manufacturing purposes; and an instance was brought to my notice, where a ship-load of what was supposed to be this mineral was obtained by surreptitious means, and sent from a distant part of the country to London. But the biter was bit, for his observation was faulty, and his cargo, proving to be calcareous spar, was worthless. It would tire out your patience to enumerate the cases in which mica or iron pyrites have been mistaken for gold. From the anxious country gentleman in our own land, to the disappointed Californian gold seeker, and to the solemn Turkish Bey mysteriously unwrapping from many a folded rag the specimen of his expected wealth, such victims of mineralogical ignorance are frequently presented to those whose pursuits bring them into a position for advising on similar points.

But there is another and a wider field far more important than the correction of isolated mistakes, in which mineralogical research has yet to be largely employed, and in which the connexion of this subject with mining is no less grave than intimate. The principles by which the accumulation of ore in lodes or metalliferous veins has been regulated are to this day so enveloped in mystery, that the prosecution of mining enterprizes is almost as much a matter of chance as it was with our forefathers

three centuries ago. Nor can we wonder that this should be the case, when we regard the peculiar difficulties by which the subject is beset. Not only is the progress of the operations so slow that the observation of one set of phenomena may extend over many years, but the examination of some points, unless made at the time of first opening, is precluded by the discolourations of water and powder smoke, or by the means adopted to secure the works. Then, according to the conditions under which the lode is placed, a combination of problems, geological, physical, and chemical, are presented for solution, and the thoughtful mining agent, left to consider them only by the light of a partial experience and natural shrewdness, is commonly led to see them through a peculiar medium, and to fall into the numerous errors resulting from unsound premises. Copious stores of knowledge have, it is true, been acquired by many of the captains and tributers in Cornwall and elsewhere; but besides the difficulty, according to the various views of individuals, in collating them, they have generally, from want of early educational opportunity, been accumulated upon an unsafe basis; and finally, the experiences perish with the men, leaving society no richer for their acquisition.

Nowhere is there more room than in the study of this subject for accurate mineralogical observation,—nowhere is the prize offered more inviting; for the resolution of some of these questions must tend to acquaint us with the probability of finding remunerative ores in certain directions, either in depth or on the course of the lodes, and must, therefore, be instrumental in discovering untold sources of wealth. Nor need we despair, when we remember the confused state of all the natural sciences little more than a hundred years since, that at some future day a more systematic cultivation, by rigorous induction, founded on close observation, will clear away the weeds, and cover with plenteous crops this hitherto barren field.

We are thus naturally led, by the contemplation of the objects to be sought for, to the second part of our subject, the Art of Mining: and here it will be necessary to dwell at greater length on the character of the studies which it is desired to embrace, inasmuch as no course of instruction in them has yet

been attempted in this country; and, strange to say, not a single book exists in the English language in which they are comprehensively treated. Among the Germans many excellent works on mining have appeared from time to time during the last three centuries; and even in France, a country comparatively so poor in mineral productions, treatises have been published, in which many of the divisions of the subject have been skilfully discussed, whilst the periodical literature of both those nations is rich in detailed descriptions of the natural phenomena and the working processes of mines in all parts of Europe. Nor are we unindebted to the Russians, whose well-educated officers of mining engineers, sent at the public expense to investigate various mineral regions of the continent, have carried back with them a treasure of valuable information, which has been in a great degree instrumental in advancing, to a high grade of perfection, the mining and metallurgical operations of the Ural and of Siberia. In Britain, however, we have little else than two or three treatises on the working of coal, and a few isolated papers on other parts of the subject; and hence it will be needful, in a series of Lectures, to depend in great part on personal experience, and to indicate, in exceptional cases, the sources whence a knowledge of details may be obtained.

But it would be an injustice to the many thinking and enterprising spirits among our British miners not to express our admiration for the skill and ingenuity which they have brought to bear on particular portions of their art. Surrounded by difficulties and dangers, they have won enduring triumphs; and in some of their applications have, by the force of persevering industry, advanced their experience with such rapid steps, that science has been glad to follow in their wake, and reap new facts to aid her further progress.

The first great feature which strikes the attention in approaching this subject is the enormous value of the mineral productions of Great Britain, amounting, as has already been stated by our honoured Director in Chief, to the sum of 24,000,000*l.* annually in the rough state. So bountifully, indeed, has our country been enriched by Providence with these sources of

wealth, and in a degree so much higher than any other region in Europe, that it need excite no surprise if those natural gifts which even aroused the industry of the early Britons, and excited the cupidity of their Roman conquerors, yield at the present day an amount of riches far greater than those produced by any other nation. Let us, then, consider the great population supported directly by the extraction of these minerals, and indirectly by their application to the arts,—the maintenance of hundreds of thousands of men by these not inexhaustible stores,—and the entire dependence of our whole manufacturing and commercial system on the supply of fossil fuel; and we cannot fail to arrive at the conviction, that in exercising the stewardship of such gifts of Heaven, the nation has a high and responsible duty to perform, that waste and improvidence are a national sin, and that it behoves all who are in any way connected with the working of our mines to lend their best endeavours to the perfecting of the most economical and efficacious means of rendering all the products of our mines available to the uses of mankind.

It is not pretended that by any plan of education in an Institution of this kind, it is possible to make a miner, or in other words, to prepare a man for taking charge of a mine as soon as he has left our walls: not more reasonably should we expect that a lad drilled in the classes of a naval college were at once metamorphosed into a sailor, fitted at once to take command of a ship. Yet surely no one will deny, that if in that school he has learnt to box the compass, to knot and splice, if he has worked out problems in navigation on sound mathematical principles, if he has been taught by descriptions how to handle a vessel at anchor in a tideway, or on a lee-shore, he will be infinitely more ready to take advantage of circumstances, and to make rapid progress, than if he had been sent on board unknowing of these things and their principles. No "royal road" to learning, no legerdemain of "cramming," can make amends for the want of time and pains bestowed on the acquisition of practice; and as with the seaman so should it be with the miner.

By description, by drawings, and models, it will be our

endeavour to make the student familiar with the chief phases of the operations practised in various regions, and under different conditions. He will have, each year, the opportunity of closely inspecting the mineral features and particular mining processes of the districts under examination by the Geological Survey; and, when furnished with this preliminary knowledge, will, I doubt not, pass to his sphere of probation better qualified to observe and to compare; whilst the practical experience which he must afterwards acquire will be superadded to what he has already benefited from the labours of others.

Before we proceed to examine farther into the general question of the importance of endeavouring to establish in Britain a system of technical education for this department, let us consider the definition and principal heads of the subject before us; and, whilst so engaged, let us take an instance from each division, illustrative of the gain to be derived from an extended acquaintance with the modes of treating it.

The art of mining comprehends all the processes whereby the useful minerals are obtained from their natural localities beneath the surface of the earth, and the subsequent operations by which many of them must be prepared for the purposes of the metallurgist.

In the first place, among these processes must be mentioned, the search for localities in which we may reasonably hope to meet with the minerals occurring either in beds or lodes. It is obvious that a combination of geological and mineralogical knowledge is requisite for success, and that a mere empirical tact obtained in a given district may lead to fatal mistakes in another. Amid the phenomena of the lodes, their frequent heaves and dislocations, and their different appearance when bounded by different rocks, call for close attention; and although from lack of sufficient and well recorded observation, the principles upon which a criterion should be founded are far from fixed, we often find that a superior degree of general experience has been rewarded by success, when mere unintelligent working had been completely foiled.

Among the methods of proving the existence of useful deposits, none has yielded greater results, or is more capable of

extended application than the art of boring. For ascertaining the position of coal-seams, and for obtaining a supply of water, bore-holes are frequently sunk in many parts of the country. But we have yet, by a comparison of the practice of different countries, and the adoption of a more economical mode of sinking, where need be, to greater depths, to increase their sphere of utility. At Neusalzwerk, near Minden, a bore-hole has lately been pierced through the trias formations, to the depth of 2,300 feet, for brine springs; and another, at Mondorf, in Luxembourg, to near 2,400 feet, which, though unsuccessful in discovering salt, has supplied a spring of above 21 cubic feet per minute. At these and various bore-holes of less depth in Germany and France, a variety of apparatus has been employed, a complete study in itself, much of which has been serviceable in greatly reducing the time and cost of such operations. We may instance the ingenious instruments of M. Degousée, the "free-falling" cutter of Herr Kind, and the hollow iron rods of Von Œynhausen, as a few of those which are well worthy of attention for the good service rendered in the execution of great works. Again, we know far too little of the routine of the Chinese well-borers, who have succeeded, according to the detailed statements of Father Imbert, in attaining the extraordinary depth of 3,000 feet, by their simple and inexpensive apparatus of rope-boring, an example which has been successfully imitated in the chalk districts of France.

The next division of importance embraces the tools used in mining. One of the greatest advantages which we enjoy over our forefathers is the use of gunpowder in rending a path through the harder rocks, which they with enduring and patient labour were obliged to cut away with hammer and wedge. But the implements employed in various districts differ not only in form and weight, but in their material and useful effect. Let me only allude to one point: in scarcely any of our mines, whether in the north or south, has it been attempted to use borers of steel; iron is almost universally, with us as in most parts of the continent, the material of which the shank of the borer is composed. Yet in Saxony, for many years past, as also in Derbyshire, and at Ecton, the work has been advantageously

carried on with borers of steel alone. Accurate experiments made and recorded at Eschweiler, and at Mansfeld in Prussian Saxony, have been attended with favourable results; and Mr. Rogers of the Abercarn Collieries has succeeded in proving, whilst sinking a large shaft in hard rock, the value of steel tools, a set of samples of which were placed in the Great Exhibition, and afterwards presented to this Museum. Although the suitable tempering of cast steel is attended with some difficulty to the inexperienced, the following reasons for its preference to the ordinary material have been established, viz., the great saving in wear and tear; the reduction of original outlay, since the stock of steel borers may be smaller than that of iron in a lower ratio than that borne by the price of iron to steel; the diminution of smith's costs for sharpening, and of time lost by boring with a blunted edge, and the greater convenience of carriage in and out of the mine. Farther, the superior compactness of the material transmits the force of a blow more efficaciously to the required point, a fact corroborated by the observation that an iron borer will cut less ground with the same number of blows when new than after being for some time in use; And it need hardly to be added, that in the questions of time, material, and cost, connected with the breaking of ground, we touch on some of the most important elements of economy in mining.

I will not detain you with an enumeration of the points to be dwelt upon in the form of the excavations by which we enter into the earth, whether by the driving of levels or the sinking of shafts under different circumstances; nor, from among the modes of securing them by timbering, masonry, or ironwork, shall I do more than bring to your notice one ingenious application of physical science to these purposes. It is well known that the sinking of a shaft through loose sand or watery rock often besets with great and sometimes with insurmountable obstacles the approach to the useful minerals which lie in firm ground below. On the banks of the Loire repeated efforts to reach the coal measures through a thick bed of alluvial sand had failed, overcome by the great influx of water and loose material; when M. Triger bethought him that the simplest

mode of vanquishing the difficulty was to dam back the water, to employ a constant resisting force which might be maintained at small expense, in place of a moving power of enormous cost. It was, in fact, to pump into the iron cylinder which formed his shaft such an amount of air that the pressure on the bottom from within should be equal to the pressure from without; and the water was thus prevented from rising above a given height. Placing a cover on the cylinder, through which two pipes are inserted, one conveying the compressed air into it, the other dipping into the watery stratum, he found a stream of water and sand poured through the latter whenever it was unable to escape rapidly enough elsewhere. Then, in order that the men might enter upon or leave their working place without disturbing the equilibrium of the forces, he applied the principle of the canal lock, fitting an upper chamber in his shaft, where, when the upper door was closed and the lower one opened, all was filled with the compressed air; when the lower one was closed and the upper opened, the air-lock was relieved from its superabundant air, and men or materials might be introduced. Pages would be filled with the details of the difficulties met and overcome, and of the successful adoption of the principle in the sinking of larger and deeper shafts; suffice it to say, that M. Triger succeeded, surrounded by water, in joining his cylinder to the solid rock at a depth of 82 feet from the surface, having proved that human life could be supported, and work done, for many hours together under a pressure of $3\frac{1}{2}$ atmospheres. His procedure is marked by manifold advantages, and admits of various applications;—witness the removal of rocks in the harbour of Croisic, on dry ground, whatever the state of the tide. Verily, if Canute had possessed a Triger among his courtiers, he might, to better purpose, have defied the rising flood to touch his royal foot!

We shall be unable here to glance even rapidly over the many systems devised for working out the minerals attained by the foregoing operations: let us only scan an isolated case. The magnificent seam called the "thick coal" of Dudley has been worked throughout the entire field on a principle which by taking the whole height, 30 feet, at one time, has been

attended with such danger as to cause almost weekly some frightful and fatal accidents, and to exercise morally a pernicious influence on the character of the colliers; whilst it has necessitated the leaving of so large a proportion in "pillars" and "ribs", that only from 11,000 to 15,000 tons of coal have been obtained out of 40,000 contained in the acre. Here then is a loss to the national wealth of useful life, and of about two thirds of the finest fossil fuel in Britain, the money value of which would amount to many millions. Yet for twenty years past, in that very district, one group of pits has been worked on a system by which the coal is taken in two successive stages, where the men work in comparative safety, and where, instead of 11,000 or 15,000, 26,000 tons are realised per acre, although the seam is there of less than its average thickness. Consider only for one moment the beneficial effects of improved means of extracting the coal from our mines: it is supposed that the total quantity annually brought into use amounts to above 30 millions of tons; and if an economy of but threepence per ton were effected, by reducing friction, ineffective labour, or other sources of wasted power, a sum of nearly 400,000*l.* per annum would be saved to the country.

We must omit to speak of the modes of transport along the underground roads, of raising the minerals to the surface, and of pumping the subterraneous water, accomplished by an amazing variety of apparatus and machines. Nor can we dwell upon that important subject of ventilation, to which our attention is so often and forcibly called by the fearful catastrophes occurring in our mines from its absence or mismanagement. I would only call attention to the rude method of dispersing noxious gases figured by Agricola 300 years ago, and in some of our districts still adopted, under the term of "brushing out the sulphur," as the only means of rendering a place safe for the men to work in. But although even at that early day more refined processes had been introduced, as evinced by his description of the ventilating fans, let us compare all those puny means, and the efficiency of ventilation in the great bulk of our collieries with the skilfully applied and fiercely blazing furnaces of some of the great northern mines, where a current of 150,000, or in

one case near 200,000 cubic feet of air in one minute are circulated through the devious passages, and rush to the upcast shaft with the velocity of a hurricane.

Nearly related to this division, as regards the question of humanity, is the true construction and the preservation of mining plans. Take an instance in which the loss of 100 lives may ensue from the ignorance of a physical fact. Those familiar with the mining districts are well aware that the great majority of their maps are laid down without any reference to the phenomenon of magnetic variation. If, then, a colliery be in operation on the dip of old workings filled with water, the tapping of which would be death to all employed in the pit, and the maps had been constructed some years previously with respect to the magnetic meridian alone, the variation may in the mean while have so far changed that the exploring drifts supposed by the manager to be going clear of the known danger may, in reality, lead him straight to destruction. The art of surveying is, however, too important and extensive to be included in the lectures on Mining, and will ultimately, we hope, form the subject of a separate course.

The last group of operations to be included is the dressing of ores, on the efficient conduct of which the success of many a mine may depend. Whilst the Schemnitz miner is able to work actual gold ores broken from great depths, which, besides a little lead, contain no more than one part of gold in 228,000 of stone,* and whilst the Russians wash in their stream-works sands containining only one part in half a million, we learn from description that the Californian and Australian are employing processes more rude than what they might have copied from the miners of three or four centuries since, and that (inasmuch as the poorer

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* In 1841-2, when I passed some months among the mines of Hungary, much had been done and was still doing by my friends the late Oberstkammergraf von Svaiczer and Mr. Rittinger, the Inspector of Stamp-works, for the improvement of the dressing of gold and silver ores; and the works at Antal and Illia, near Schemnitz, were well worthy of admiration for their scale and economy.

part can only be profitably worked in conjunction with the richer) they are actually losing for ever a large proportion of the riches showered by nature upon those lands.*

Such are, in few words, the processes which will form the substance of a course of instruction in the art of mining; and it need scarcely to be observed that a preparatory acquaintance with physics, geology, and practical mechanics is indispensably necessary. For this reason it is proposed that the Lectures on Mining shall be given to the students of the second year, already provided with the preliminary studies, some of which have been commenced; but in order to obviate misconstruction, it is proposed during the present season to deliver a concise course, intended simply as an outline of the subject, leaving the more detailed treatment for the ensuing year.

Amid the entire circle of the sciences we can hardly mention one which the accomplished miner may not at some time call to his aid, from the science of numbers, on which all his other knowledge should be based, up to astronomy, which may assist in the construction of his maps. We cannot, indeed, expect that many will become, like Humboldt, (who was educated, and for some time practised, as a miner,)† master in several sciences; but when we add to these the acquaintance with business routine and commercial questions which the manager of mining property ought to possess, is it not clear as the noon-day that for those who desire to excel in this profession a special education ought to be superadded to the training of our schools and colleges? And is it not equally clear that with so vast a field of investigation before him the intelligent inquirer must ever remain a student, whilst only the shallow pretender can affect to be

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* "Le désordre administratif et l'ignorance profonde, qui jusqu'ici ont présidé à ces sauvages opérations techniques, nous font présenter combien les lavages des terrains auriféres doivent être imparfait dans la péninsule, combien d'or y est perdu pour les générations futures!"—*Humboldt, Letter to M. Fay.*

† Alexander Von Humboldt was a student at the mining academy of Freiberg, in Saxony, in 1791, with von Buch, Freiesleben, and other coryphœi of mineralogical and geological science.

the arbiter of the difficult problems which daily present themselves?

From the examples above adduced I trust that I shall be justified in asserting, that a communication of knowledge, whether of the principles or of the practices involved in mining, must be attended by great pecuniary gain to the country at large. We shall be met, in the outset, by the argument more suited to the Cape Boer or the Chinese than to the progressive Anglo-Saxon, that because our fathers have done very well without it we may easily dispense with any such innovation; and that the immense mineral production of Britain is the best proof that we need not to follow the example of nations unable, with all their schooling, to rival us in that respect. But let us not overlook the great natural advantages with which we have been favoured, nor forget, that although individual perseverance has done much, very much, among us, we must still depend for advancement in a great degree on the experience of others. In good truth "he that neglects the culture of ground naturally fertile is more shamefully culpable than he whose field would scarcely recompense his husbandry: and it is as rational to live in caves till our own hands have erected a palace, as to reject all knowledge of architecture which our understandings will not supply."*

Taking even the present state of our knowledge as a standard, let us balance the argument on such crucial questions as the following. Do cases occur in which mineral substances are neglected from ignorance of their nature? Is it true or not, that others are wasted and lost to the nation by the character of the present operations? Do not crowds of well-meaning adventurers rue their introduction to the mining schemes of impostors? Are not hundreds of human lives sacrificed to a want of precaution and prudence? Is not the condition of machinery and apparatus in a great part of the country very inferior to certain now existing models? Are there not numerous sources of wealth lying unemployed from the uncertainty consequent on a

* Johnson. Rambler, No. 154.

want of former records or present knowledge? No one, I am confident, acquainted practically with our mineral districts, will hesitate in replying, that in all these points great and salutary changes may be made, and that enlarged opportunities of learning accorded to the mine agents must produce their fruits in due season.

As for the miserable plea of ignorance, that the country cannot fail to prosper, in whatever degree her sons may squander the stores of nature deemed inexhaustible,—it but leads the mind back, through many centuries, to an instance of similar reckless boasting, followed by a warning fate. In the palmy days of Athens, when the silver mines of Laurion were vivifying art, commerce, and luxury, Xenophon asserted, in a formal treatise on the revenues of the state, that "whatever number of men had been employed in those silver mines, no diminution had been practically effected in the quantity of the ores;—that there was no limit to the productiveness of the veins, either in depth or in extension, and that their riches, in fine, were inexhaustible."* Let any one contrast such assurances with the beggared state of the land ever since.

I would be far from strictly comparing the conditions of Attica or its people with our own; but we must bear in mind, that in all our mining districts the minerals are extracting at a fearful rate, and each year in an increasing ratio, and that after a certain lapse of time scarcity and increase of price must necessarily follow. In the meanwhile, we have numerous rivals in other and less favoured lands, doing their utmost to make up for natural disadvantages by fostering education and acquiring a sound knowledge of the principles on which they act. In this race they have often been checked by political troubles and peculiarities in their social relations; but, having so thoroughly secured each onward step as to be comparatively independent of

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* Μαρτυρεῖ δὲ κἀκεῖνο, ὅτι, εἰργασμενῶν ἀνθρώπων ἐν τοῖς αργυρίοις ἐν τῷ παντὶ χρόνῳ ἀναριθμήτων, νῦν οὐδὲν διαφέρει τα ἀργύρια ἢ ἃ οἱ πρόγονοι ἡμῶν ὄντα ἐμνημόνευον αὐτα. . . Οὔτε γὰρ βάθους πέρας οὔτε ὑπονόμων οἱ ὀρύττοντες εὑρίσκουσι.—*Xen. de Vect.* c. IV.

the fleeting skill of individuals, they nevertheless press forward again in the same path; and when the day comes that our preponderance in natural treasures is reduced to something nearer equality,—when deeper and thinner coal seams must be wrought, when poorer ores of the metals must be more highly prized, and when the products of our manufactures can only be brought into commerce at higher prices,—then must the star of England's prosperity decline, unless we keep our vantage ground by the superior skill and knowledge to which technical education must greatly contribute.

Thus far we have directed our attention almost exclusively to the material advantages, or, in other words, the pecuniary returns to be expected from the cultivation of these subjects. I have dwelt so long on such topics because the main object of the foundation of this course of instruction has reference to that point of view.

But I should ill appreciate the character of this audience, and do violence to my own feelings, were I not, in conclusion, to protest against that debasing spirit which would decry all branches of knowledge except those which are at once commercially profitable, and which would practically inculcate a belief that the acquisition of money is intended to be the great end and aim of human existence. Shall we, for their own sake, examine the works of the architect, the painter, or the poet, and analyze the rules upon which his art is founded, whilst we yet remain indifferent to any one department of the rich storehouse of nature, opened for man's inspection by the Author of all things?

Believe me, that the phenomena of mineralogy, and the principles which regulate them, are, though different in their kind, no less beautiful than those of animal and vegetable life; and they possess the additional source of interest, that they may guide us to the wider sphere of speculating rationally on the constitution of the orbs which roll with us through endless space.

With reason has a Turkish author* said, "Consecrate, O my

* Nabi Effendi, a counsellor of Sultan Mustapha III.

son, the aurora of thy reason to the study of the sciences; in the vicissitudes of life they are an infinite resource, they form the mind, they polish the understanding, they instruct man in his duties, they delight and amuse us in prosperity, they become our consolation in adversity." Indeed, to the student in his cabinet, no less than to the traveller through Alpine passes, or over regions explored by the skill of the miner, the study of minerals offers at the same time an attractive recreation, and an efficient method of disciplining the faculty of observation. The closer we investigate the principles on which their constitution and their physical properties depend, the more are we startled by new and convincing proofs that it is only the imperfection of our knowledge which as yet prevents us from seeing more than the glimmering outline of that harmony which pervades all the works of nature. The system of law, the *νόμος ὁ πάντων βασιλεὺς* of Pindar, working as surely in the particle which vanishes from our power of sight, as in the loftiest mountain mass, reveals itself with more distinctness the farther we advance; and although the difficulties of inquiry are heightened, so are its pleasures also increased by the ties of brotherhood, which springing hence unite our pursuits with the other natural sciences.

Nor let it be supposed that the details of mining are unproductive of advantage to any but the professional miner. Deep in the bowels of the earth the labour of generations has wrought out edifices no less worthy of admiration than those which the skill of the architect has reared upon her surface; and if, in the latter case, we esteem it desirable to learn so much of the principles of the art as may enable us to appreciate the design of the craftsman, so in the former shall we find in the magnitude of the operations, in the diversity of the natural appearances brought to light, and in the ingenuity of the processes adopted for the maintenance and extension of the works, a harvest of facts no less interesting than suggestive of farther inquiry.

Whatever may be the imperfection of the teacher of these subjects, there is in themselves so much that is exact, so much that is vast, so much, in fine, that is most worthy of man's highest powers, that we may hope, out of the number who will

enter with us on the curriculum, to see some few, at least, who will not stop short at that point whence they may obtain their worldly ends, but will persevere towards that goal of higher knowledge which has been, and always will be, the object of the noblest of mankind.

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